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# COMMENT ON VIKOR METHOD BY COMBINING THIS METHOD AND LINEAR ASSIGNMENT

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**Abstract**

**Purpose:** the purpose of this comment is to propose a new algorithm which shows the same result of Linear Assignment and Vikor method.

**Findings:** For finding new methods to solve multi criteria problems, we need to know the older ones, so at the first of paper we present a comprehensive description of the steps that we need to solve problems by Vikor and Linear Assignment Method and after, we show three example that we solved with new method. At the end we will Compare the results of new method and the old one in Conclusion part.

**Limitation:** These two methods come from two different sub-model , vikor is belong to compromising subgroup and Linear assignment is belong to concordance subgroup.

**Value :** The new method does not need any condition that is use in last step of vikor method . One other advantage that this new way present is ranking all alternatives at the end.

**Key words:** Multiple criteria decision making (MCDM); Vikor method; Linear assignment Method; Dual condition

**Paper type:** comment paper

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## Introduction

As regards the Dual condition that is use in Vikor method at The final section , we find that this method make user Confused , so we suggest to use R , S and Q ( we will describe these signs in next parts ) as equiponderant Criteria in assignment method for ranking the alternatives . In this paper we would like to present two example that the first one is simple and the second one is more complicated with more criteria.

We follow the first three steps of Vikor method and make a matrix with the help of R, S and Q and then solve this matrix by Linear assignment Method.

## Literature Review

Decision making describes the process through which, the solution of certain problems can be chosen (Hwang and Yoon, 1995). Most important decisions in organizations are made by groups of managers or experts. Managers spend much of their time in decision related meetings (Huber, 1984). Balancing tradeoffs between objectives is even more important in groups than for individuals, because conflicting objectives and opposing viewpoints are inevitably going to exist. Sycara (1991) presented a framework for problem restructuring based on the goals and goal relationships of the negotiating parties, recognizing this multiplication of goals.

Decision making groups can range from cooperative with very similar goals and outlooks, to antagonistic with diametrically opposed objectives. Even in cooperative groups, conflict can arise during the decision process (Poole et al., 1991). If group members have different viewpoints, some method of aggregating preferences and reconciling differences are needed. MCDM methods have been developed to solve conflicting preferences among criteria for single decision makers (Corner and Kirkwood, 1991; Keeney and Raiffa, 1976; Korhonen et al., 1984; Saaty, 1980).

The concordance method generates a preference ranking which best satisfies a given concordance measure. The Linear Assignment Method is one of the examples in this family. In this method it is believed that an alternative having many highly ranked attributes should be ranked high [Hwang and Yoon, 1981].

The principle of MADM is to select the best alternative from several mutually exclusive alternatives based on their general performance of multiple attributes (or criteria). According to the types and the characteristics of decision problems, different MADM methods have been designed and implemented in various domains such as Linear Assignment method, TOPSIS, ELECTRE, etc.

Among these approaches, linear assignment method [3] uses concordance concept and linear programming (LP) model to determine the rank of alternatives. Since this method only requests the ordinal data instead of cardinal data, it is easy to understand and to be implemented in different domains. However, this approach still has several weaknesses that can be improved. First of all, this approach can only deal with precise information. In reality, that the precise information is available is unrealistic. Secondly, this approach can only deal with two types of attributes: benefit type and cost type. For some problems, the best attribute value is not the highest value or the lowest value, but the target value. The importance of target type's attribute should not be ignored. Thirdly, this approach does not consider actual cardinal difference between alternatives on each attribute. Hence, even two alternatives have the same rank on two attributes the actual cardinal difference between alternatives on each attribute can be quite large.

In this method, each alternative priority at every attribute is used to achieve a Zero-One Programming model and through the solution of this model, all alternatives will be ranked. The main procedure of the linear assignment method for the selection of the best alternative from among those available is described by Asgharpour (1992), Azar (2002) and Hwang and Yoon (1981).

**The Linear Assignment Method**

The proposed linear assignment method to determine the proper ranking order of alternatives by applying linear assignment principle. The detailed algorithm of our approach is explained as follows:

**Step1**. For example we have a matrix like this:

$$D = \begin{array}{c c} & \begin{array}{ccc} x_1 & \cdots & x_n \end{array} \\ \begin{array}{c} A_1 \\ \vdots \\ A_m \end{array} & \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \end{array}$$

**Step2.** we can determine the ranking orders of alternatives for each attribute. Determine the ranking order of alternatives for each attribute. Its attribute wise ranking matrix will become.

$$r = \begin{array}{c} \\ 1st \\ 2nd \\ 3rd \end{array} \begin{array}{c} \begin{array}{ccc} x_1 & \dots & x_n \end{array} \\ \begin{bmatrix} A_i & \cdots & A_i \\ \vdots & \ddots & \vdots \\ A_m & \cdots & A_m \end{bmatrix} \end{array}$$

**Step3.** Assign the proper weight for each rank of individual alternative.

The traditional linear assignment model neglects the importance of actual cardinal difference between alternatives on each attribute. The proposed approach will consider actual cardinal difference and compute the weight for each rank of individual alternative.

$$r = \begin{array}{c} \\ 1st \\ 2nd \\ 3rd \end{array} \begin{array}{c} \begin{array}{ccc} x_1 & \dots & x_n \end{array} \\ \begin{bmatrix} W(A_i) & \cdots & W(A_i) \\ \vdots & \ddots & \vdots \\ W(A_m) & \cdots & W(A_m) \end{bmatrix} \end{array}$$

**Step4.** Convert the weight matrix into concordance matrix. Based on the weight matrix, we can construct a concordance (square) matrix r, whose element $r_{ij}$ is the summation of the weights for all attributes where alternative i is ranked j. For instance, the concordance matrix of above example will be computed as below:

$$r = \begin{array}{c} \\ A_1 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccc} 1st & 2nd & 3rd \end{array} \\ \begin{bmatrix} W(A_i) & \cdots & W(A_i) \\ \vdots & \ddots & \vdots \\ W(A_m) & \cdots & W(A_m) \end{bmatrix} \end{array}$$

**Step 5.** Form the linear assignment (LP) model:

$$max: \sum_{i=1}^{m} \sum_{k=1}^{m} r_{ij} . P_{ik}$$

$$st: \sum_{k=1}^{m} P_{ik} = 1 \;\; ; i = 1, \dots, m$$

$$\sum_{i=1}^{m} P_{ik} = 1 \; ; k = 1, \dots, m$$

$$P_{ik} = 0 \; or \; 1$$

Where $P_{ik}$ = 1 if $\boldsymbol{A}_i$ is assigned to overall rank j. Otherwise, $P_{ik}$ = 0

**Step6**. Solve the LP model. The result is:

$$P^* = \begin{bmatrix} 0 \; or \; 1 & \cdots & 0 \; or \; 1 \\ \vdots & \ddots & \vdots \\ 0 \; or \; 1 & \cdots & 0 \; or \; 1 \end{bmatrix}$$

**Step7.** The optimization options is:

$$A^* = A.P^* = [A_1 \quad \dots \quad A_m] \begin{bmatrix} 0 \; or \; 1 & \cdots & 0 \; 0r \; 1 \\ \vdots & \ddots & \vdots \\ 0 \; or \; 1 & \cdots & 0 \; or \; 1 \end{bmatrix}$$

**The Vikor Method**

Multi Criteria Decision Making (MCDM) methods is a branch of a general class of Operations Research models which deal with the process of making decisions in the presence of multiple objectives. This class is further divided into Multi Objective Decision Making (MODM) and Multi Attribute Decision Making (MADM) (Pohekarand Ramachandran , 2004). These methodologies share the common characteristics of conflict among criteria, incommensurable units, and difficulties in design/selection of alternatives (Huang et al., 1995).

The VIKOR method is an effective toll in MCDM. This method introduces the multicriteria ranking index based on the particular measure of “closeness” to the “ideal” solution, *F** (Opricovic and Tzeng, 2004). The compromise solution $F^c$ is a feasible solution that is the “closest” to the ideal solution, and compromise means an agreement established by mutual concessions.

Within the VIKOR method, the various *j* alternatives are denoted as $a_1, a_2, \dots, a_j$. For alternative $a_j$ the rating of the $i_{th}$ aspect is denoted by $f_{ij}$ , i.e., $f_{ij}$ is the value of the $i_{th}$ criterion function for the alternative $a_j$ ; *n* is the number of criteria . The compromise ranking algorithm VIKOR has the following steps (Opricovic and Tzeng , 2004):

**Step1**. Determine the best $f_i^*$ and the worst $f_i^-$ values of all criterion functions, *i* = 1, 2, … , *n* . If the $i_{th}$ function represents a benefit then $f_i^* = \max_j f_{ij}$ and $f_i^- = \min_j f_{ij}$ , while if the $i_{th}$ function represents a cost $f_i^* = \min_j f_{ij}$ *and* $f_i^- = \max_j f_{ij}$ . *so we will* make *:*

$$f_i^* = \{f_1^*,\ f_2^*, \dots f_n^*\}$$

$$f_i^- = \{f_1^-,\ f_2^-, \dots f_n^-\}$$

**Step2.** Compute the values $S_j$ and $R_j$ , J= 1 , 2 , … j by the relations :

$$S_j = \sum_{i=1}^{n} w_i\,(f_i^* - f_{ij})/(f_i^* - f_i^-)$$

$$R_j = \max_i [w_i (f_i^* - f_{ij})/(f_i^* - f_i^-)]$$

wherein $W_i$ are the weights of criteria, expressing the decision maker´s preference as the relative importance of the criteria. The weights of relative importance of the attributes may be assigned using AHP (Saaty, 2000). The steps are explained below in the following way:

1. Find out the relative importance of different attributes with respect to the objective. To do so, one has to construct a pair-wise comparison matrix using a scale of relative importance. The judgments are entered using the fundamental scale of the AHP. An attribute compared with itself is always assigned the value 1 so the main diagonal entries of the pair-wise comparison matrix are all The numbers 3, 5, 7, and 9 correspond to the verbal judgments “moderate importance”, “strong importance”, “very strong importance”, and “absolute importance” (with 2, 4, 6, and 8 for compromise between the previous

values). Assuming *n* attributes, the pair-wise comparison of attribute *i* with attribute *j* yields a square matrix $A_{nxn}$ where $a_{ij}$ denotes the comparative importance of attribute *i* with respect to attribute *j*. In the matrix, $a_{ij} = 1$ when i=j and $a_{ij=1}/a_{ij}$

2. We need to know the vector $W = \{w_1, w_{2,\dots}\, w_n\}$ which indicates the weight that each criteria is given in pair-wise comparison matrix *A*. To recover the vector *W* from *A* we outline a method in a two-step procedure:

- For each of the *A´s* column divide each entry in column *i* of *A* by the sum of the entries in column *i*. This yields a new matrix, called *Anorm* (for normalized) in which the sum of the entries in each column is 1.
- Estimate *Wi* as the average of the entries in row *i* of *Anorm*.

Once we have the Pair wise Comparisons matrix it is necessary checking it for consistency.

After Compute the values of $S_j$ , $R_j$ we have to go next step

**Step3.** Compute the values $Q_j$ , by the relation:

$$Q_j = v(S_j - S^*)/(S^- - S^*) + (1-v)(R_j - R^*)/(R^- - R^*)$$

Wherein

$$S^* = \min_j S_j \;;\; S^- = \max_j S_j \;;\; R^* = \min_j R_j \;;\; R^- = \max_j R_j$$

And v is introduced as a weight for the strategy of maximum group utility, whereas (1− *v*) is the weight of the individual regret. The solution obtained by is with a $min_j S_j$ maximum group utility (“majority” rule), and the solution obtained by is $min_j R_j$ with a minimum individual regret of the “opponent”. Normally, the value of *v* is taken as 0.5. However, *v* can take any value from o to 1.

**Step4.** Rank the alternatives, sorting by the values *S*, *R*, and *Q* in decreasing order. The results are three ranking lists. Propose as a compromise solution the alternative $A^{(1)}$ which is the best ranked by the measure *Q* (minimum), if the following two conditions are satisfied:

a. Acceptable advantage . $Q(A^{(2)}) - Q(A^{(1)}) \geq DQ$ where $DQ = 1/(J-1)$

and *A*(2) is the alternative with second position in the ranking list by *Q*;

b. Acceptable stability in decision making. The alternative $A(1)$ must also be the best ranked by $S$ or/and $R$. This compromise solution is stable within a decision making process, which could be the strategy of maximum group utility (when $v > 0.5$ is needed), or "by consensus" ( $v \approx 0.5$ ), or with veto ( $v < 0.5$).

If one of the conditions is not satisfied, then a set of compromise solutions is proposed which consists of:

c. Alternative $A^{(1)}$and $A^{(2)}$if only condition b is not satisfied, or

d. Alternatives , $A^{(1)}, A^{(2)}, \ldots, A^{(m)}$ if the condition a is not satisfied .$A^{(m)}$ is determined by the relation $Q(A^{(m)}) - Q(A^{(1)}) < DQ$ for maximum $n$ (the positions of these alternatives are "in closeness").

Ranking the alternatives by the VIKOR method gives us, as a compromise solution.

**Recommended model :**

As mentioned vikor method has four step , in our solution The first three steps are repeated but then we will make a matrix with three Criteria that are $x_R, x_S, x_Q$ and n rank per n alternatives like this : $(M_n)$

$$\begin{array}{cc} & \begin{matrix} x_S & x_R & x_Q \end{matrix} \\ \begin{matrix} rank1 \\ \vdots \\ rankn \end{matrix} & \begin{bmatrix} \vdots & \vdots & \vdots \end{bmatrix} \end{array}$$

Figure (1)

Now it is time to use assignment method and keep solving problem with this method.

Note1 : the new alternatives do not have weight , so we can consider same weight like this ( $x_S$ , $x_R$ , $x_Q$ = 1 ) or in more complicated situation that we have two or more alternative with same position it's better to use these weight ( $x_S: 1$ , $x_R: 1$ , $x_Q: 2$)

**Numerical example:**

**Example1:**

In order to apply the Vikor method, we have selected five alternatives and five Criteria. This problem is based on Metal selected projects and we just want to solve it with our way.

Material and their attributes

| Attributes | 304 | 321 | 316 | 2205 | 254 |
|---|---|---|---|---|---|
| Yield strength(ys) | 230 | 263 | 301 | 621 | 725 |
| Tensile strength(TS) | 500 | 589 | 602 | 841 | 901 |
| Hardness (HRB) | 73 | 80 | 83 | 293 | 310 |
| PRE | 17.5 | 17 | 23.1 | 35 | 43 |
| Risk of failure | 5 | 5 | 5 | 2 | 1 |
| Cost(C) $/Tm | 3200 | 3800 | 5000 | 20000 | 40000 |

**Step1.**

| | YS | TS | H | Cost | PRE | RF |
|---|---|---|---|---|---|---|
| | max | min | min | max | max | min |
| $f_i^*$ | 621 | 500 | 73 | 40000 | 43 | 1 |
| $f_i^-$ | 230 | 841 | 293 | 3200 | 17 | 5 |

**Step2.**

| | A1 | A2 | A3 | A4 | A5 |
|---|---|---|---|---|---|
| $S_j$ | 0.8294 | 0.7646 | 0.7093 | 0.1400 | 0.6088 |
| $R_j$ | 0.4495 | 0.4116 | 0.3679 | 0.0774 | 0.3656 |

**Step3.**

| | A1 | A2 | A3 | A4 | A5 |
|---|---|---|---|---|---|
| $Q_j$ | 1 | 0.920 | 0.803 | 0 | 0.727 |

**Step4**. In this step we have two approaches:

1. Continue the main way like the role that we said, 2. Use this new method, According to new method, this step is related to make matrix that we mentioned in figure (1).

$$M_n = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{ccc} x_S & x_R & x_Q \end{array} \\ \begin{bmatrix} 0.8294 & 0.4495 & 1 \\ 0.7646 & 0.4116 & 0.92 \\ 0.7093 & 0.3679 & 0.803 \\ 0.1400 & 0.0774 & 0 \\ 0.6088 & 0.3656 & 0.727 \end{bmatrix} \end{array}$$

From this point onwards we are going to use assignment method Note2: pay attention that all of this three alternative should be considered negative. As result we will have:

**Step 5.**

$$\begin{array}{c} \\ R1 \\ R2 \\ R3 \\ R4 \\ R5 \end{array} \begin{array}{c} \begin{array}{ccc} x_S & x_R & x_Q \end{array} \\ \begin{bmatrix} A_4 & A_4 & A_4 \\ A_5 & A_5 & A_5 \\ A_3 & A_3 & A_3 \\ A_2 & A_2 & A_2 \\ A_1 & A_1 & A_1 \end{bmatrix} \end{array}$$

| | Rank1 | Rank2 | Rank3 | Rank4 | Rank5 |
|---|---|---|---|---|---|
| $A_1$ | 0 | 0 | 0 | 0 | 3 |
| $A_2$ | 0 | 0 | 0 | 3 | 0 |
| $A_3$ | 0 | 0 | 3 | 0 | 0 |
| $A_4$ | 3 | 0 | 0 | 0 | 0 |
| $A_5$ | 0 | 3 | 0 | 0 | 0 |

If we accept that w = {1, 1, and 1} we will have:

$$\textbf{Step6.}\ [A_1\, A_2\, A_3\, A_4\, A_5].\begin{vmatrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{vmatrix} \rightarrow A_4 > A_5 > A_3 > A_2 > A_1$$

If we do Vikor method exactly like main way, we will reach to same result. Ranking the alternatives by the Vikor method gives us, as a compromise solution, the alternative $A_4$ . This alternative, is the best ranked by Q. In addition, conditions 6-a and 6-b are satisfied as this alternative is also the best ranked by S and R.

But sometimes problems are more complicated than this one and we can't find best alternative simply. In this situation we have to use weights for each criterion. For making weighted matrix we will use entropy method.

Example 2:

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ | $C_{13}$ | $C_{14}$ | $C_{15}$ | $C_{16}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $A_1$ | 66 | 79 | 63 | 75 | 70 | 78 | 70 | 78 | 58 | 82 | 56 | 83 | 74 | 59 | 76 | 66 |
| $A_2$ | 70 | 72 | 72 | 68 | 69 | 72 | 74 | 72 | 67 | 68 | 57 | 75 | 72 | 66 | 77 | 66 |
| $A_3$ | 79 | 72 | 72 | 75 | 75 | 72 | 77 | 73 | 72 | 70 | 67 | 75 | 75 | 67 | 77 | 69 |
| $A_4$ | 77 | 70 | 74 | 71 | 77 | 74 | 79 | 80 | 75 | 67 | 63 | 70 | 74 | 70 | 80 | 65 |

After doing the calculations

| rank \ index | $x_S$ | $x_R$ | $x_Q$ |
|---|---|---|---|
| $A_1$ | 0.595 | 0.095 | 0.752 |
| $A_2$ | 0.756 | 0.074 | 0.642 |
| $A_3$ | 0.366 | 0.065 | 0.008 |
| $A_4$ | 0.360 | 0.098 | 0.500 |

By using entropy method

W= {0.06, 0.1, 0.84}

Ranking:

| rank \ index | $x_S$ | $x_R$ | $x_Q$ |
|---|---|---|---|
| $A_1$ | $A_4$ | $A_3$ | $A_3$ |
| $A_2$ | $A_3$ | $A_2$ | $A_4$ |
| $A_3$ | $A_1$ | $A_1$ | $A_2$ |
| $A_4$ | $A_2$ | $A_4$ | $A_1$ |

Number of repeat:

| | Rank1 | Rank2 | Rank3 | Rank4 |
|---|---|---|---|---|
| $A_1$ | 0 | 0 | 2 | 1 |
| $A_2$ | 0 | 1 | 1 | 1 |
| $A_3$ | 2 | 1 | 0 | 0 |
| $A_4$ | 1 | 1 | 0 | 1 |

| | Rank1 | Rank2 | Rank3 | Rank4 |
|---|---|---|---|---|
| $A_1$ | 0 | 0 | 0.1+0.06 | 0.84 |
| $A_2$ | 0 | 0.1 | 0.84 | 0.06 |
| $A_3$ | 0.1+0.84 | 0.06 | 0 | 0 |
| $A_4$ | 0.06 | 0.84 | 0 | 0.1 |

$$A^* = [A_1\ A_2\ A_3\ A_4]\begin{bmatrix}0 & 0 & 0 & 1\\ 0 & 0 & 1 & 0\\ 1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\end{bmatrix} = A_3 > A_4 > A_2 > A_1$$

In this example if we don't use weights, we can't rank alternatives.

**Example 3:**

$$\begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array}\begin{array}{c} \begin{array}{ccc} x_S & x_R & x_Q \end{array} \\ \begin{bmatrix} 1.47 & 0.54 & 0 \\ 1.49 & 0.8 & 0.86 \\ 2.53 & 0.92 & 1.37 \\ 2.06 & 0.80 & 1.13 \\ 1.56 & 0.72 & 0.87 \end{bmatrix} \end{array}$$

By using entropy method

W= {0.25, 0.08, 0.64}

Ranking:

| rank \ index | $x_S$ | $x_R$ | $x_Q$ |
|---|---|---|---|
| $A_1$ | $A_1$ | $A_1$ | $A_1$ |
| $A_2$ | $A_2$ | $A_5$ | $A_2$ |
| $A_3$ | $A_5$ | $A_4$ | $A_5$ |
| $A_4$ | $A_4$ | $A_2$ | $A_4$ |
| $A_5$ | $A_3$ | $A_3$ | $A_3$ |

Number of repeat:

| | Rank1 | Rank2 | Rank3 | Rank4 | Rank 5 |
|---|---|---|---|---|---|
| $A_1$ | 3 | 0 | 0 | 0 | 0 |
| $A_2$ | 0 | 2 | 0 | 1 | 0 |
| $A_3$ | 0 | 0 | 0 | 0 | 3 |
| $A_4$ | 0 | 0 | 1 | 2 | 0 |
| $A_5$ | 0 | 1 | 2 | 0 | 0 |

| | Rank1 | Rank2 | Rank3 | Rank4 | Rank 5 |
|---|---|---|---|---|---|
| $A_1$ | 0.25+0.08+0.66 | 0 | 0 | 0 | 0 |
| $A_2$ | 0 | 0.25+0.66 | 0 | 0.08 | 0 |
| $A_3$ | 0 | 0 | 0 | 0 | 0.25+0.08+0.66 |
| $A_4$ | 0 | 0 | 0.08 | 0.25+0.66 | 0 |
| $A_5$ | 0 | 0.08 | 0.25+0.66 | 0 | 0 |

$$A^* = [A_1\ A_2\ A_3\ A_4\ A_5]\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} = A_1 > A_2 > A_5 > A_4 > A_3$$

As it is seen the alternative $A_1$ is the best rank by Vikor method and Linear Assignment method.

**Conclusion:**

If we consider to the two note that we have expressed, we will have new way with the Algorithm that we have expressed on Sixth step. We could solve 20 examples by this method and at the end we had similar results with previous methods.

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